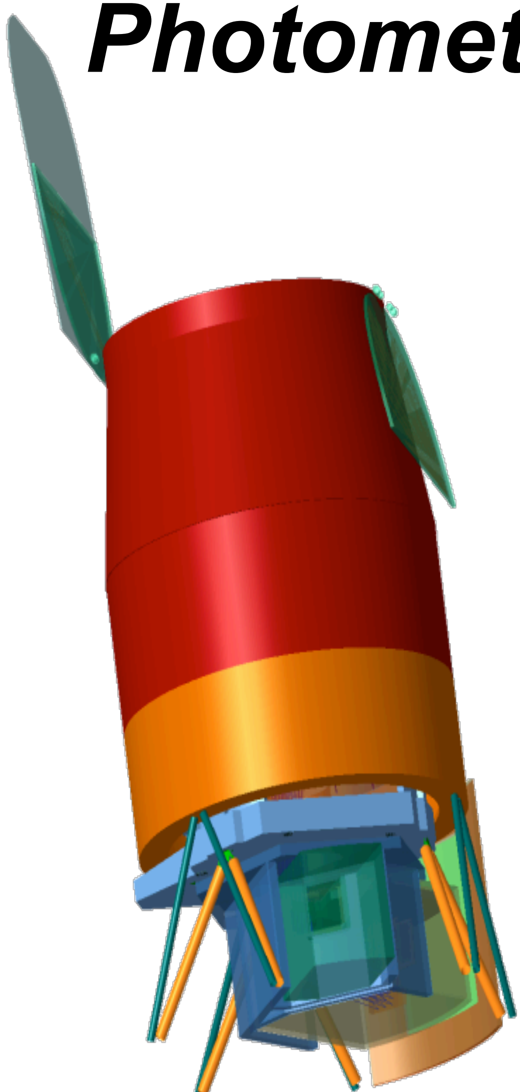
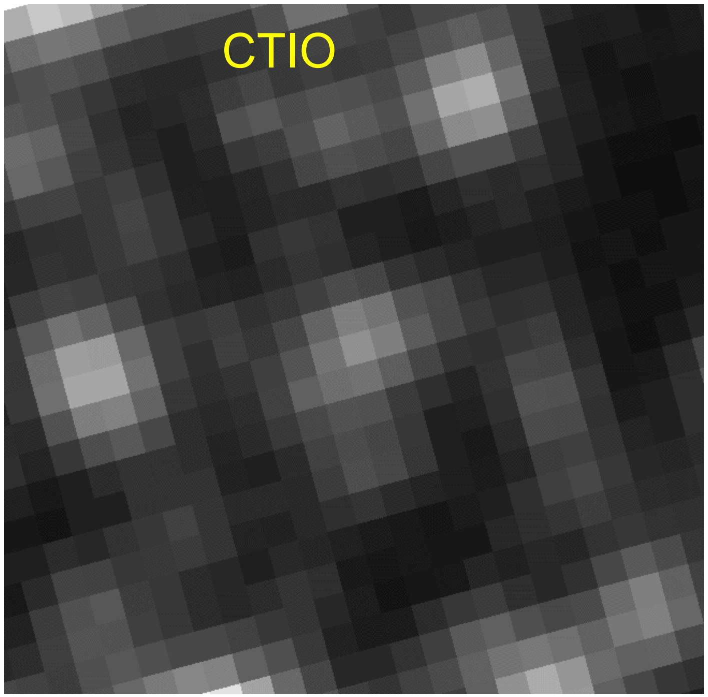
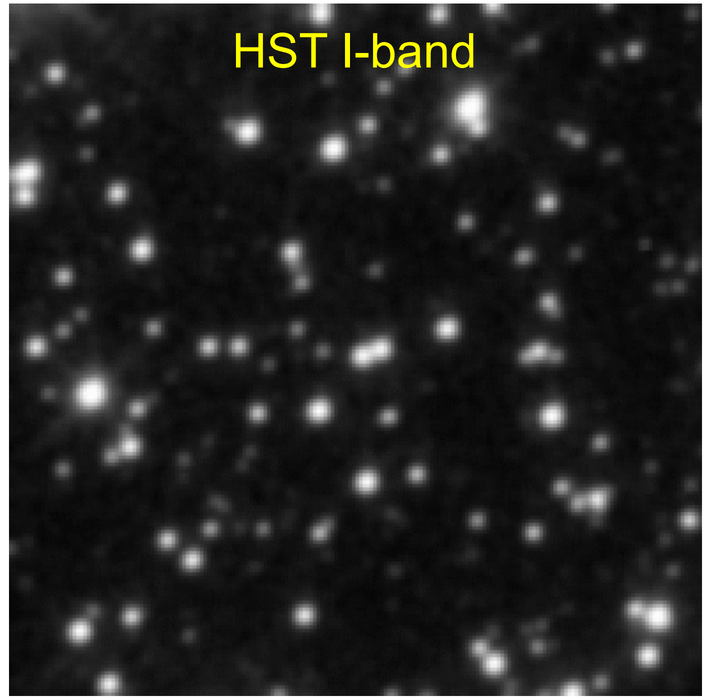
WFIRST-AFTA
Exoplanet Microlensing Photometry+Astrometry Pipeline

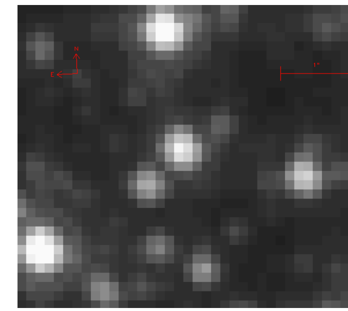


David Bennett
University of Notre Dame

New Photometry/Astrometry code needed







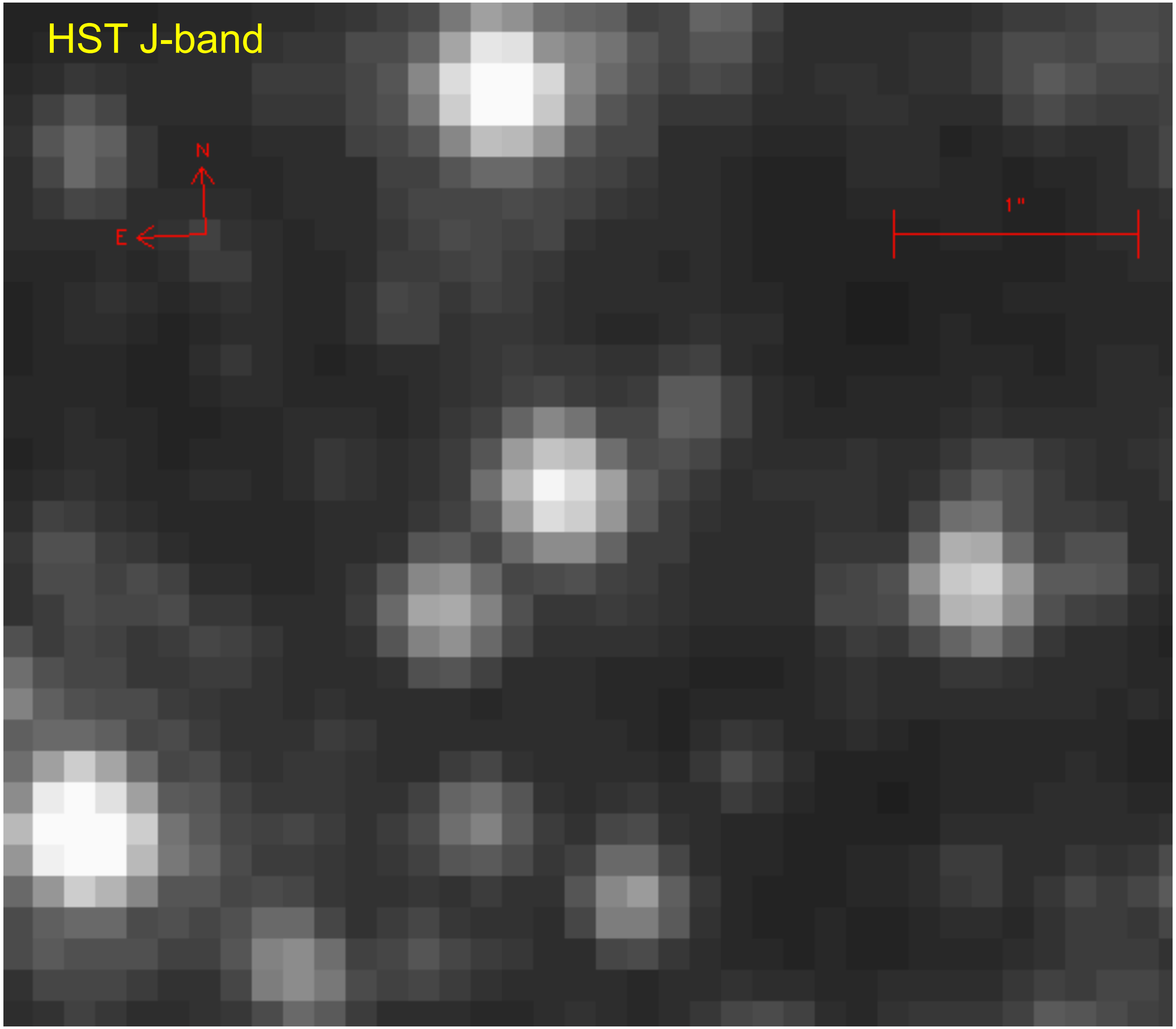
HST J-band

- These images are from MACHO fields with low extinction
- WFRIST-AFTA fields will be closer to the plane with 2-3 × the stellar density
- Proper motion of neighbor stars will be a significant source of photometry errors
- A time series of HST/WFC3/IR data will allow us to test photometry code

Blow-up of HST/WFC3/IR Image

More stars, because the IR luminosity function is flatter.

Most stars are not completely blended, but the images overlap.



Microlensing Survey Stars Will Not Be Isolated

- Proper motion of neighboring stars will contribute to photometry noise
- We need astrometry information for our determination of host star properties
- We want a WFIRST-AFTA exoplanet microlensing pipeline that generates
  - Photometry
  - Astrometry
  - A catalog of detector defects

- Develop exoplanet microlensing photometry+astrometry pipeline pre-launch using HST/WFC3/IR data

Crowded Field Photometry

- PSF fitting photometry
  - not optimal for ground-based microlensing because we can’t locate individual stars
- Difference image photometry (DIA)
  - Target star location clear from isolated signal in difference image

- WFIRST differs because
  - Very stable PSF (much better than HST)
  - Proper motion effects are large
    - Standard DIA not likely to be accurate
  - PSFs in W149 filter are color-dependent
  - Strong parallax effects between spring and fall seaons
- PSF fitting photometry is likely optimal
  - but should include proper motions, parallax and color dependent PSF
  - Jay Anderson’s HST analysis code is a good starting point

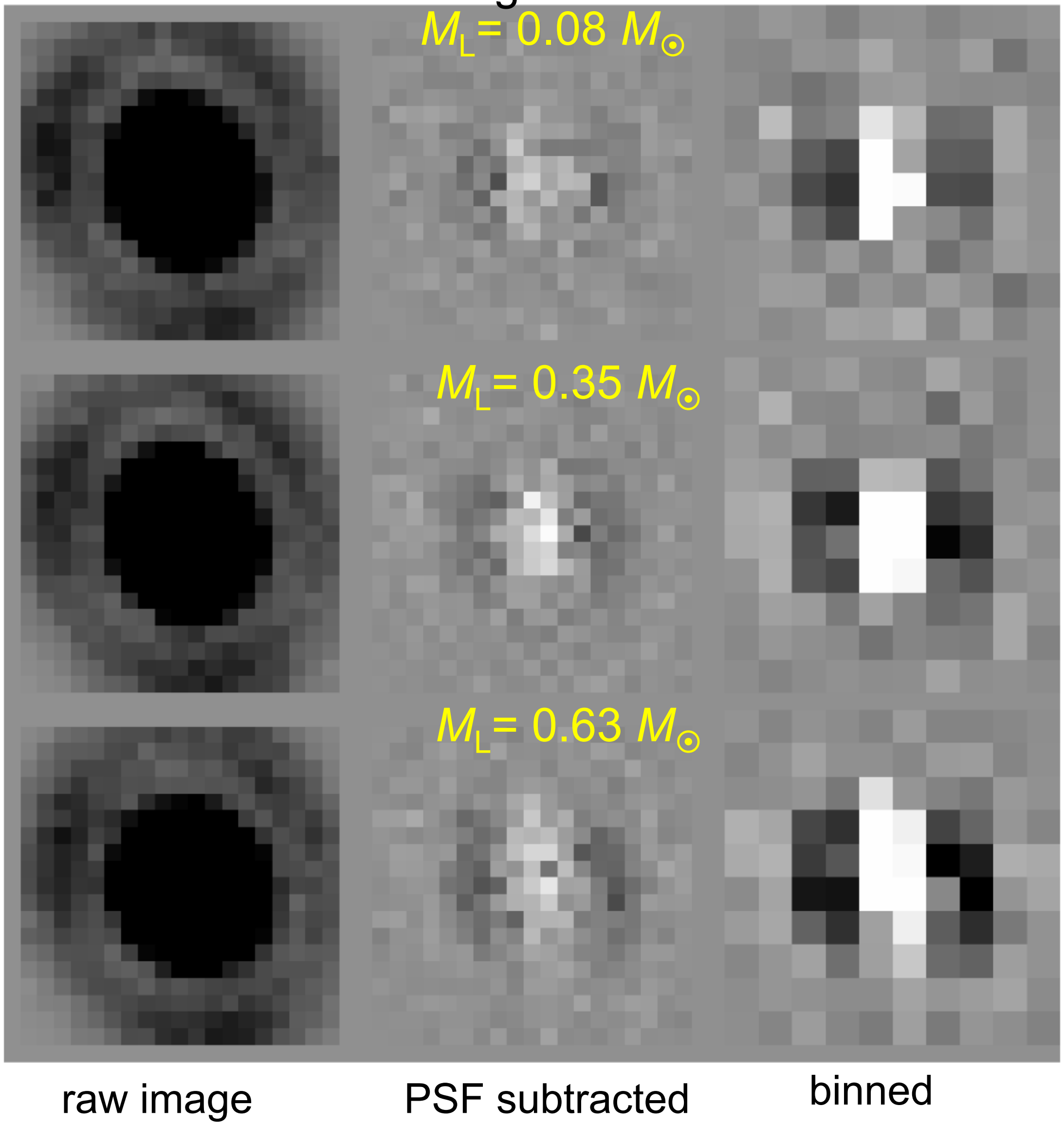
WFIRST Microlensing Pipeline

- Solve for photometry, color, and astrometry (proper motion and parallax) of each star
- Solve for detector effects, and their change in time
  - detector radiation effects
  - temperature effects
  - changing hot pixels
  - PSF shape changes
- What calibration data are needed by other programs?
- Microlensing pipeline can likely be used for a calibration field in the LMC, which is observable at anytime

Lens Star Identification from Space

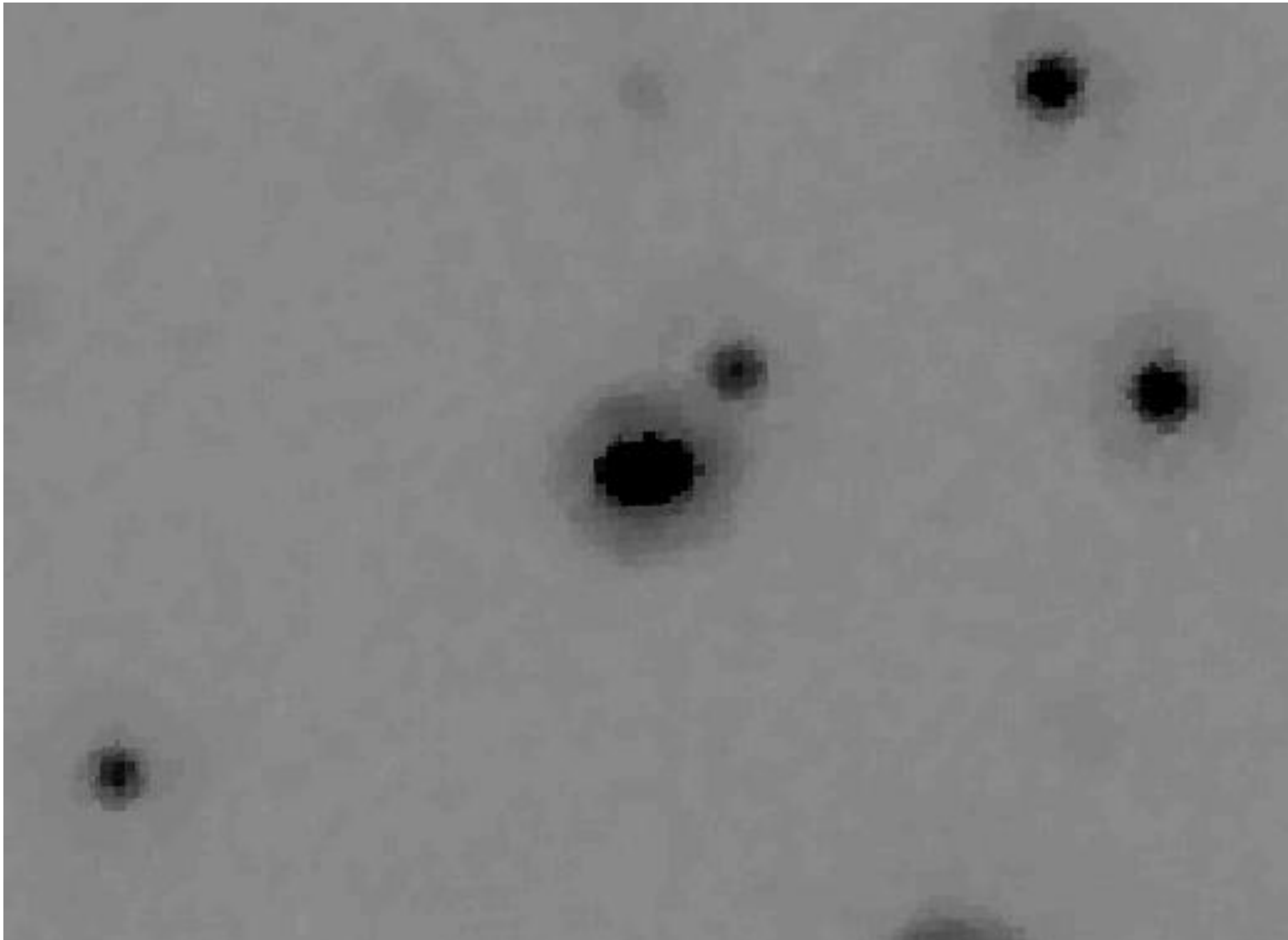
- Lens-source proper motion gives $\theta_E = \mu_{\rm rel} t_E$
- $\mu_{\rm rel}$= 8.4±0.6 mas/yr for OGLE-2005-BLG-169
- Simulated HST ACS/HRC F814W (I-band) single orbit image “stacks” taken 2.4 years after peak magnification
  - 2× native resolution
  - also detectable with HST WFPC2/PC & NICMOS/NIC1
- Stable HST PSF allows clear detection of PSF elongation signal
- A main sequence lens of any mass is easily detected (for this event)

Simulated HST images:



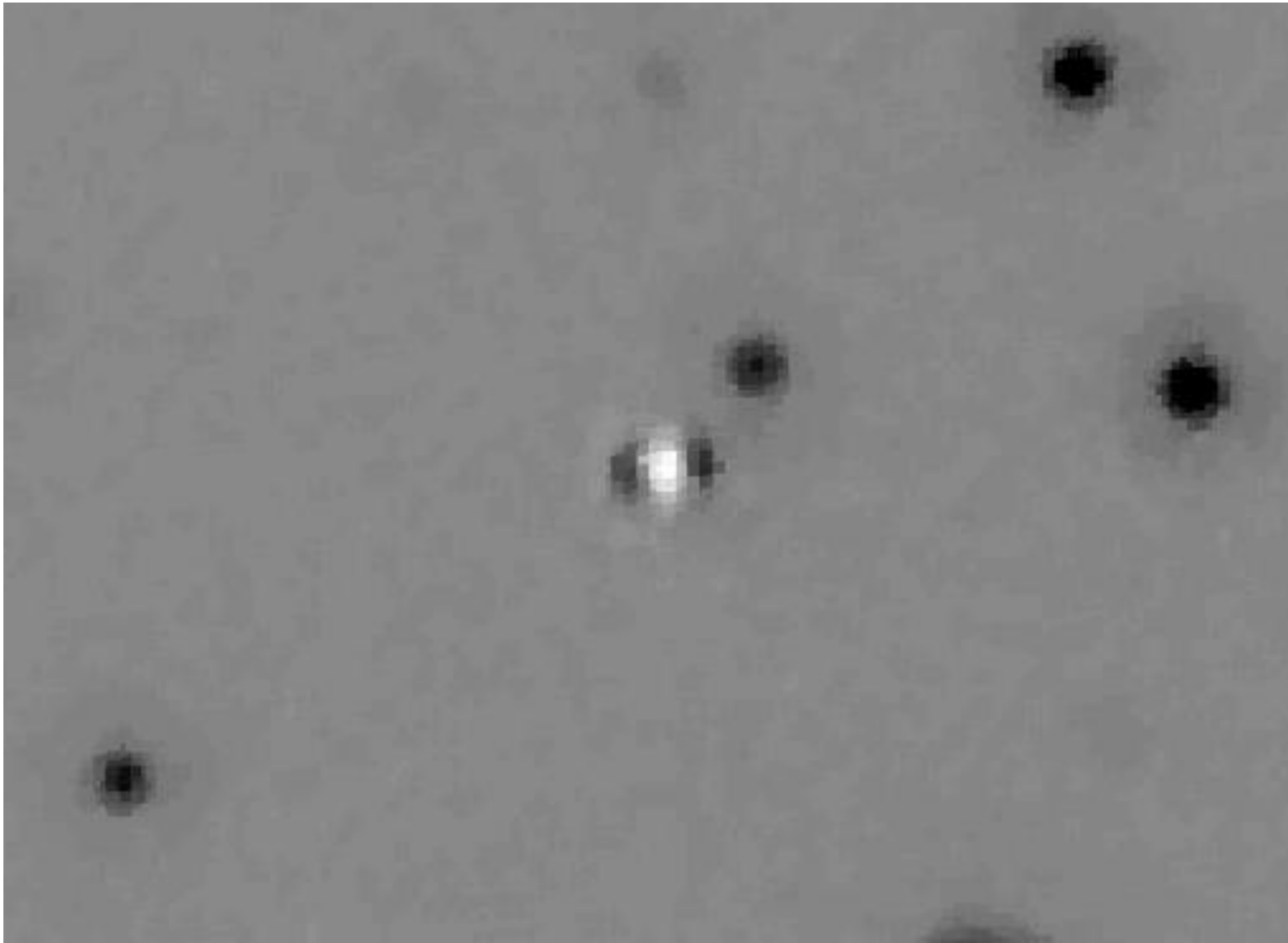
Stacked HST I-band Image of OGLE-2005-BLG-169 Source

Source *looks* elongated relative to neighbors



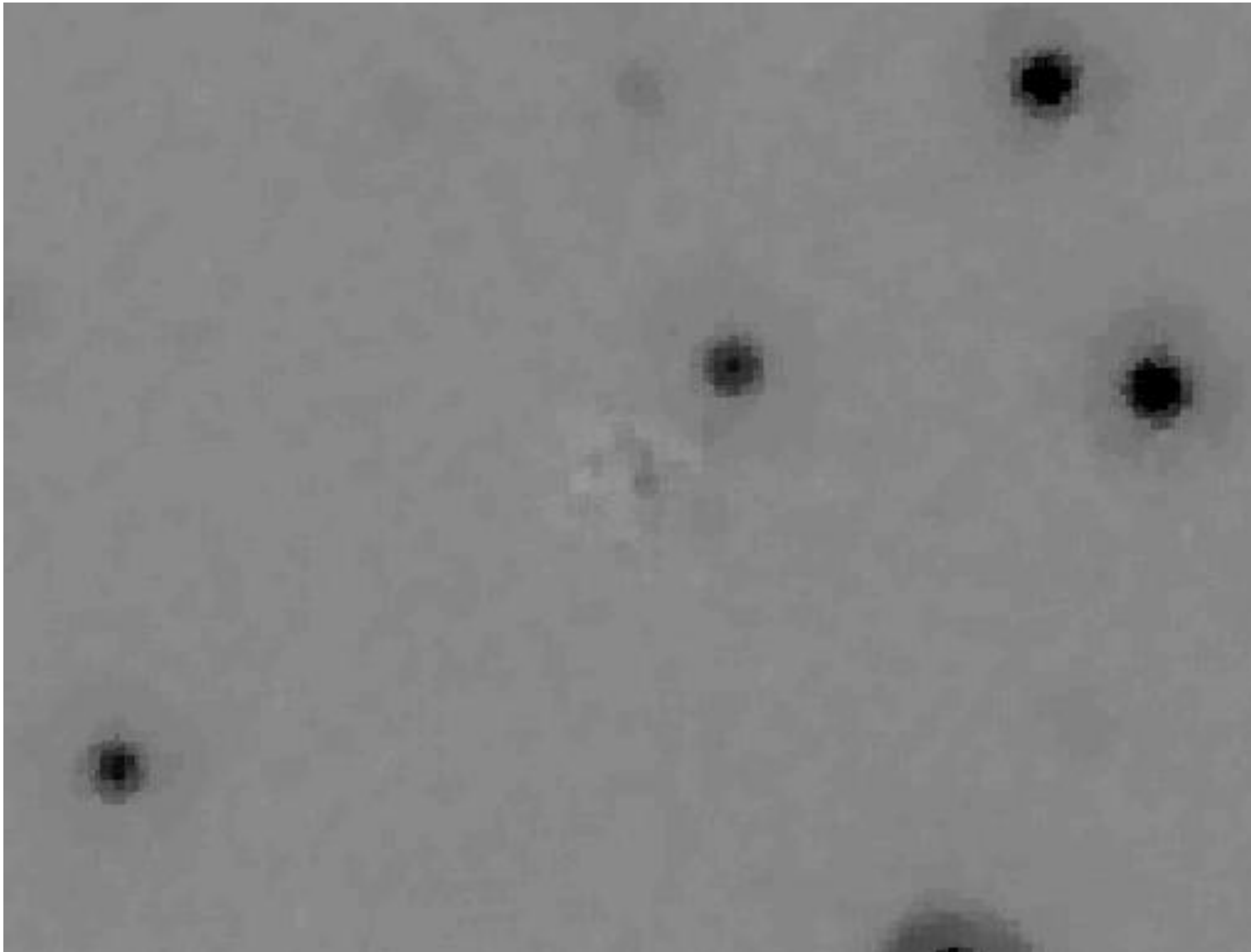
PSF for a Single Star Subtracted

Residuals
in X when
we subtract
a PSF from
each image
and stack…



Fit and Subtract Two Stars: Source & Lens

Very good subtraction residuals when we fit for *two* sources



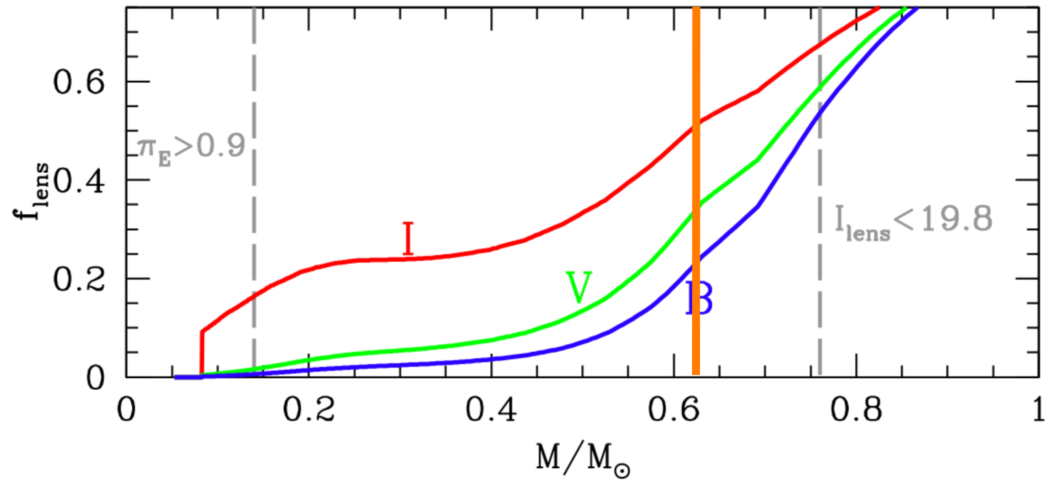
Lens+Source Solution:

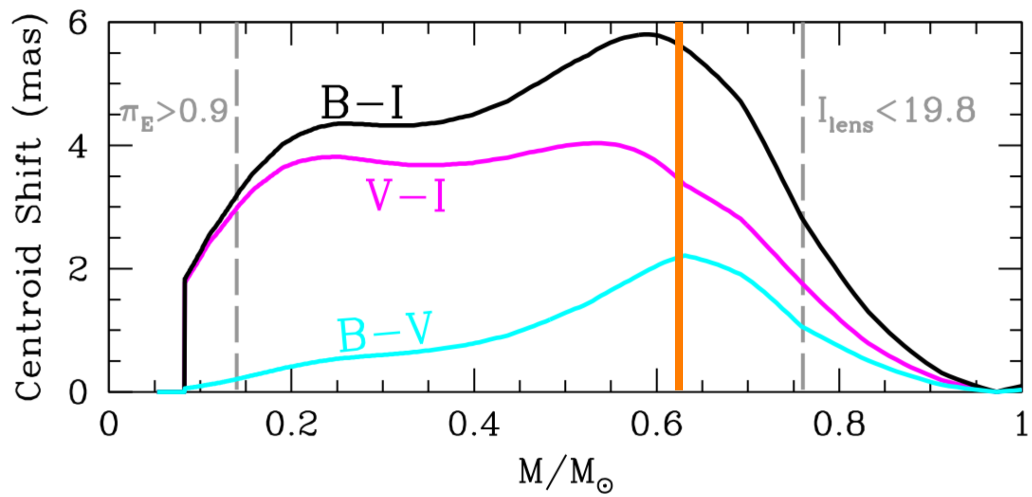
- Offset consistent in the F814W, F555W, and F438W data:
  - Δx = 1.25 pixels = 50 mas
  - Δy = 0.25 pixel = 10 mas
  - FLUX: (left) (right)
    - F814W 3392 e^- 3276 e^-
    - F555W 2158 e^- 3985 e^-
    - F438W 338 e^- 1029 e^-
    - $f_I = 0.51$
    - $f_V = 0.35$
    - $f_B = 0.25$

HST BVI observations imply

$M_* = 0.63\ M_\odot$

$M_p = 17\ M_\oplus$





observed separation of 51 mas confirms planet model prediction of 54.3±3.7 mas